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X-RAYS FROM FISSION

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X-RAYS FROM FISSION

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Date of Contract	1 April 1972
Contract Number	N00014-67-A-0126-0012
Amount of Contract	$167,505.00
Contract Expiration Date	31 December 1972
Short Title of Work	X-Rays from Fission
Principal Investigators	C. Fred Moore, Professor of Physics G. W. Hoffmann, Asst. Professor of Physics

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I. INTRODUCTION

This is a report on the activities pursued during the nine months of the contract "X-Rays from Fission". Much of the effort during the previous two contract years has been to study fission yields from experiments in which fragment mass was not determined directly. These experiments involved coincidence measurements between X-rays and/or gamma-rays. During the course of these experiments it was found that the K X-rays and the gamma-rays emitted at the time of fission come primarily from nuclear, rather than atomic, processes. Since nuclear properties vary in no systematic fashion from one nucleus to another, these types of experiments are not now being pursued because the extraction of fission isotopic yields from such experiments appears to be in the distant future. During the present contract period a time-of-flight tube has been constructed and tested. All effort is now being devoted to the extraction of isotopic fission yields from the data of energy-time-of-flight-induced L-X-ray coincidence experiments. The test and preliminary data obtained are quite promising.

II. FISSION FRAGMENT TIME-OF-FLIGHT

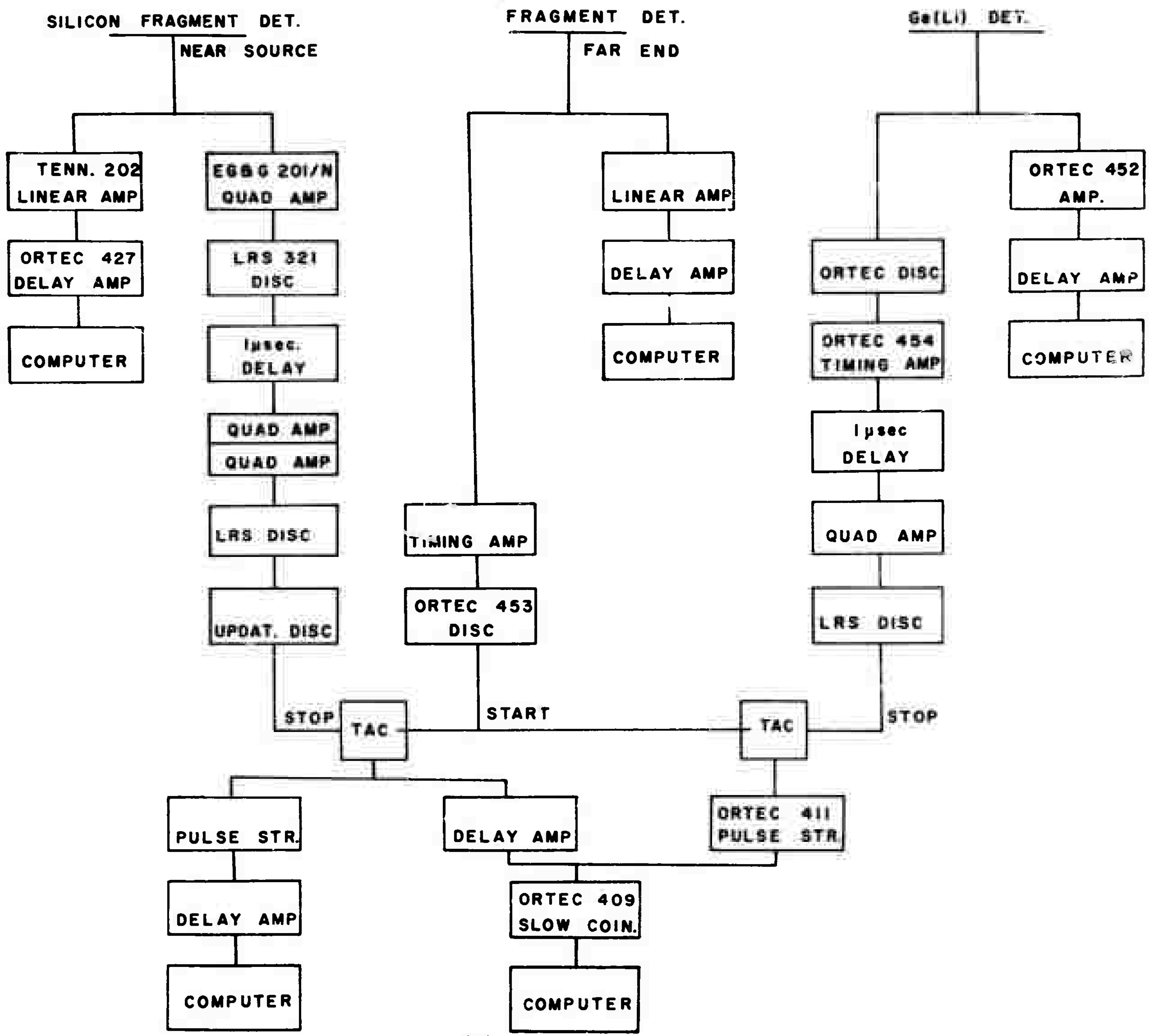
Post-neutron mass distributions (for binary or tertiary fission) can be determined by measuring the time-of-flight of one fragment over some distance and its kinetic energy. As discussed in the previous Annual Report, in order to obtain a mass resolution of 1 a.m.u. (FWHM) so that the integral nuclear mass distribution (i.e., quantized A yields) may be unfolded from the experimental mass spectrum with a great degree of certainty, one needs a long flight path (of the order of 10m) and a large solid angle (of the order of 5 msr). However, a 10m flight path implies a vanishingly small solid angle (4×10^{-2} msr for a 300 mm^2 detector). Oakey and MacFarlane [Nucl. Instr. Methods 49 (1967) 220] have shown that this problem can be overcome by using an electrostatic particle guide. Such a guide, which consists of a wire at a negative high voltage running down the center of a cylinder the length of the flight path, allows electrostatic focusing of charged particles - the ions emitted in an angular range of the order of 2° are confined to trajectories around the central wire as they traverse the guide. The collection efficiency of such an electrostatic particle guide is proportional to the ionic change and the voltage on the wire and inversely proportional to the fragment energy (see the calculations in the previous Annual Report, for example).

As reported in the last Annual Report, an electrostatic particle guide of the above type was constructed at The University of Texas Center for Nuclear Studies. Although this guide performed as expected, it was found that it was necessary to locate the detector some distance from, and shielded from, the central wire because of the negative voltage on the wire. A new particle guide with modifications to avoid these problems has been constructed. This guide consists of two 12m long, concentric, stainless steel tubes with inside diameters of 4 and 1.7 inches. The inner tube is maintained at a high positive voltage and has a 20 mil wire at ground potential running its length. The guide was extensively tested and found to perform satisfactorily. A 1m extension has been added to the target end of the particle guide so that the second fragment detector will not be in a high neutron flux when neutron-induced-fission studies are done.

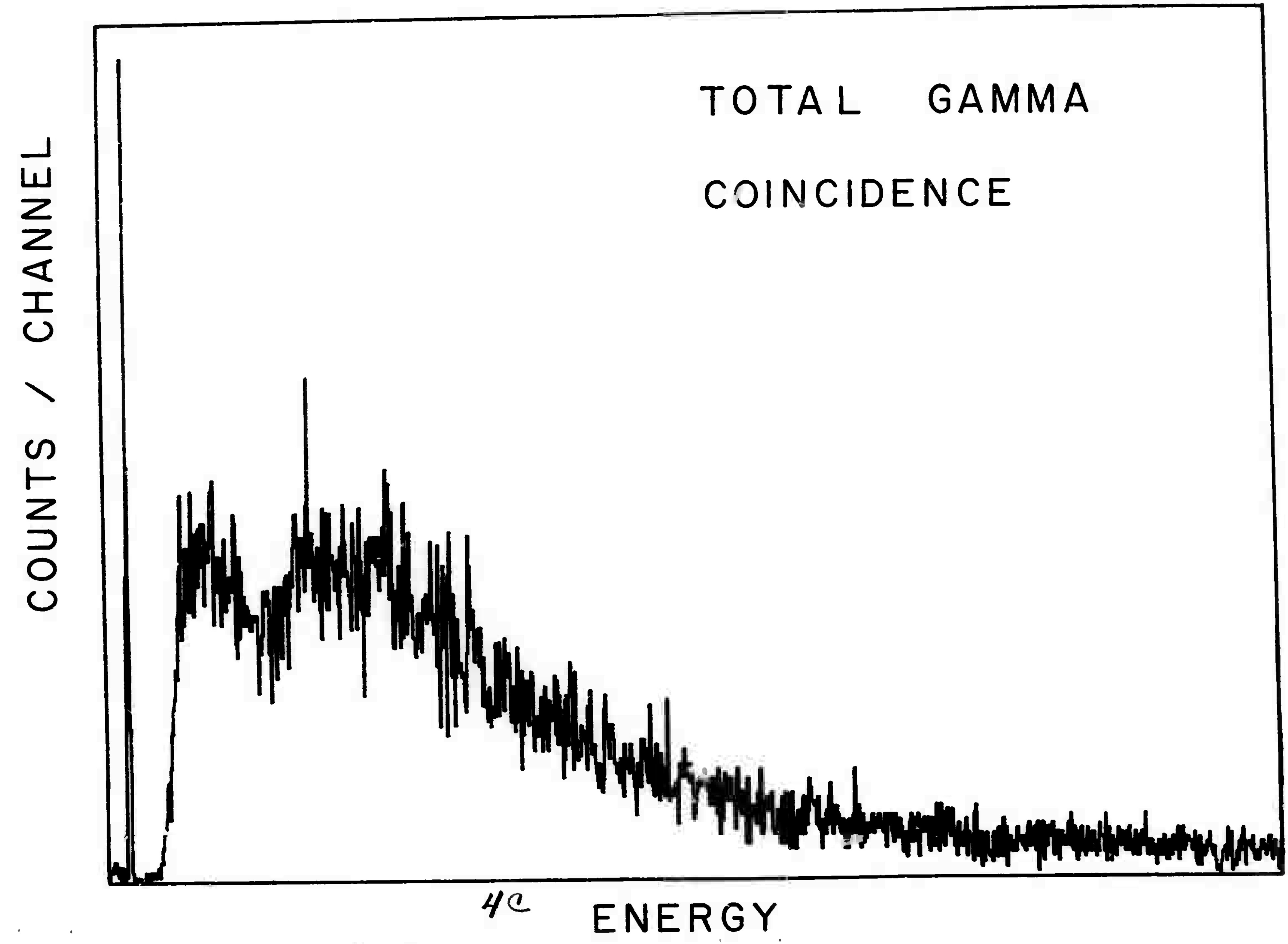
Various simple timing and coincidence experiments were done with the 12m electrostatic particle guide and a ^{252}Cf source in order to test the performance of the guide, the electronics, and the detectors. A variety of detectors were tried and promising results with good resolution were obtained using an ORTEC 130 fission-fragment detector.

A new 0.09 μg ^{252}Cf source has been received and is now being used to do an energy-time-of-flight-gamma-ray coincidence experiment to test the mass resolution of the system. A Si surface-barrier detector is located in the target chamber behind the target, while the ORTEC 130 fission-fragment detector is located at the far end of the particle guide. A low-energy-photon detector is positioned to look at the target. All three detectors are cooled. A triple coincidence is required between the two fission fragments and a gamma ray. The count rate for this triple coincidence is approximately one count per minute. The energies of both fission fragments and the gamma rays are recorded on magnetic tape for off-line analysis. The enclosed figures contain a schematic of the electronics circuitry used and several of the singles spectra obtained, as well as the total unsorted mass spectrum. Gated spectra obtained by gating on particular gamma rays by use of the computer are being measured. Although the gated spectra thus far accumulated do not contain a significant number of counts, promising detail is now visible.

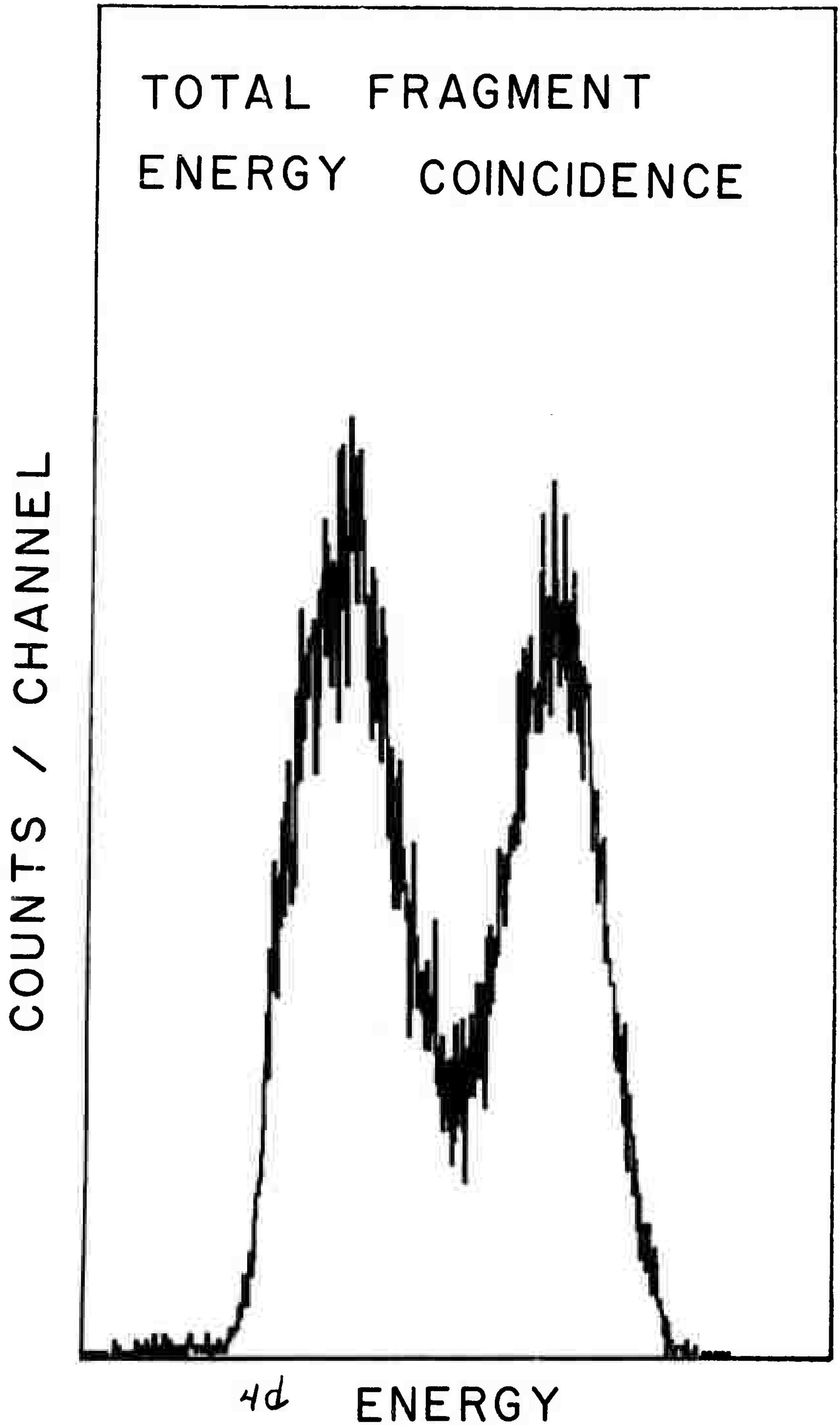
The PDP-15 computer being used to collect the data has been programmed to do all necessary data analysis. The TC520/TC620/TC501 PHA system of the computer has been repaired and updated recently by the manufacturer.

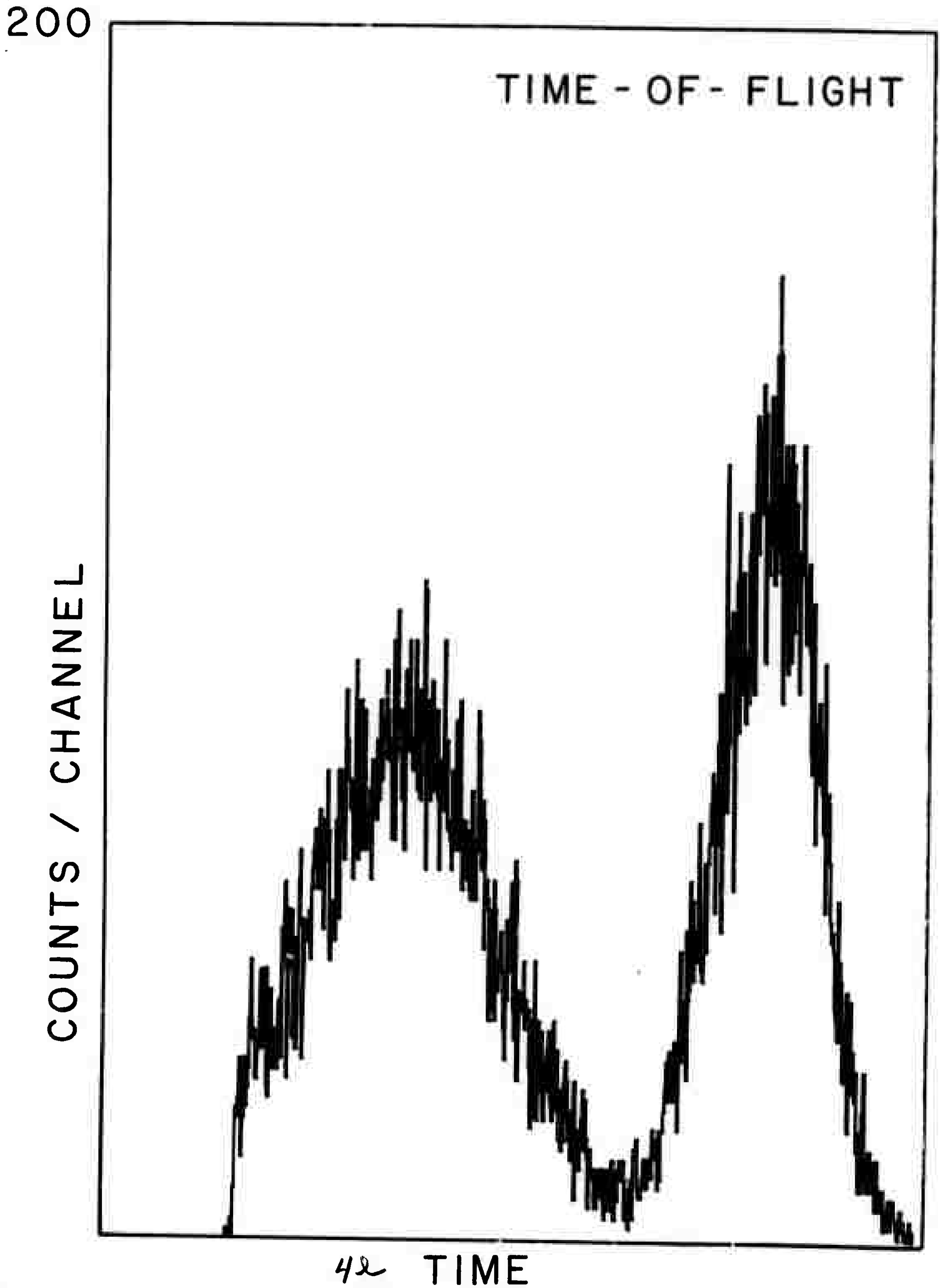


SILICON FRAGMENT DET.
NEAR SOURCE
FRAGMENT DET.
FAR END
Ge(Li) DET.
TENN. 202 LINEAR AMP
ORTEC 427 DELAY AMP
COMPUTER
EG&G 201/N QUAD AMP
LRS 321 DISC
1μsec. DELAY
QUAD AMP
QUAD AMP
LRS DISC
UPDAT. DISC
STOP
TAC
START
TIMING AMP
ORTEC 453 DISC
LINEAR AMP
DELAY AMP
COMPUTER
ORTEC DISC
ORTEC 454 TIMING AMP
1μsec DELAY
QUAD AMP
LRS DISC
STOP
TAC
ORTEC 452 AMP.
DELAY AMP
COMPUTER
PULSE STR.
DELAY AMP
COMPUTER
DELAY AMP
ORTEC 409 SLOW COIN.
COMPUTER
ORTEC 411 PULSE STR.



4c


TOTAL FRAGMENT
ENERGY COINCIDENCE
COUNTS / CHANNEL
4d
ENERGY



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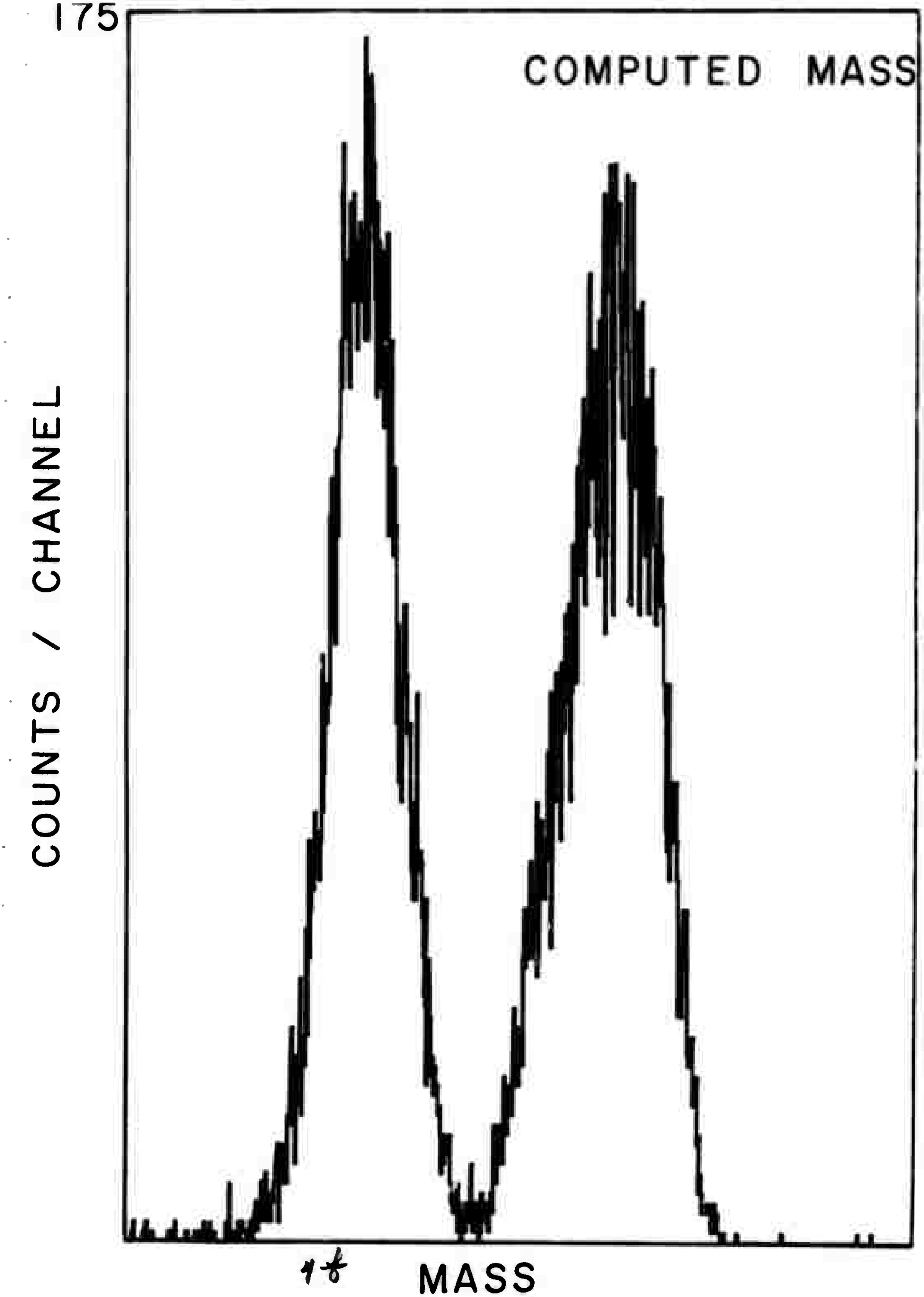
175
COMPUTED MASS
COUNTS / CHANNEL
MASS

III. TIME-OF-FLIGHT-ENERGY-X-RAY COINCIDENCE MEASUREMENTS FOR THE DETERMINATION OF ISOTOPIC FISSION YIELDS

Time-of-flight-energy measurements only allow mass determination. In order to obtain isotopic fission yields both charge and mass must be determined simultaneously. Direct physical techniques usually involve measuring in coincidence, at the time of fission, parameters from which Z and A can be determined. With present day resolution in photon spectroscopy, any characteristic X-rays emitted from the fission fragments may be experimentally observed to unambiguously identify the nuclear charge of these fragments. Such observations will only identify particular fission fragment elements and no statements about elemental yields may be made unless the origin(s) of these observed X-rays are known.

A seemingly appropriate technique to determine nuclear charge, in which X-rays associated with the fission fragments are observed and the origin of the X-rays is well understood, has been tested at the Center for Nuclear Studies. This technique is to create vacancies in the electron shells of the fragments by a known atomic process and observe the fluorescence yields (the probability that a vacancy in a given shell results in a radiative transition). Since the fluorescence yields have been measured experimentally and are understood theoretically, extraction of fission charge and isotope yields should be straightforward. The electron vacancies may be created by allowing the fission fragments to pass through a thin foil (such as carbon). The X-rays resulting from electron transitions may be observed with a high resolution photon detector situated near the foil. An experiment was performed in which fission fragments were detected in coincidence with X-rays produced when the fragments passed through a thin carbon foil. It was observed that two groups of L-X-rays (corresponding to the light and heavy fragments) were produced. The resolution was not good enough (due to the rather poor detector used) to resolve individual lines, but the peaks were located in the energy region where the L-X-rays were expected to appear. Thus, this technique seems to work as expected and the technology seems to be at hand to determine fission yields with a very reliable method.

In the last Annual Report a possible triple coincidence experiment using the time-of-flight-energy-X-ray techniques to measure fission isotopic yields was presented. In this experiment the fissioning source was placed at one end of the particle guide with a fission fragment detector placed on line with the center of the guide behind the source.

Another fission fragment detector was placed at the other end of the 12m guide. A thin carbon foil was placed in front of this detector and observed by a high resolution photon detector. The fragment detector near the source provided the start pulse and the other fragment detector provided the stop pulse for the time-of-flight measurement. The electronics were arranged to require a triple coincidence between the pulses in both fragment detectors and the pulse in the X-ray detector.

Two modifications to the above triple coincidence experiment are needed and both are allowed by the 1m extension which has been added to the 12m electrostatic particle guide. The placing of the carbon foil in front of the fragment detector located 12m from the source removes the X-ray detector from the vicinity of high neutron fluxes but also causes an energy uncertainty in the fragments reaching the fragment detector. Since this energy is an important parameter in the experiment, it is necessary to have the best energy resolution possible. Since high neutron fluxes will also degrade the performance of the fragment detectors, the second fragment detector should be moved from the vicinity of the target. Now that the 1m extension has been added to the particle guide, the second fragment detector can be placed 1m from the source and the carbon foil can be placed in front of this fragment detector since an accurate measurement of the energy of the second fission fragment is not necessary.

The above modifications in the placement of the detectors may necessitate modifications in the triple coincidence circuitry given in the last Annual Report. However, computer studies are now underway to determine if the same basic circuitry can be used and corrections can be made by the use of kinematic calculations made by the computer without degrading the energy resolution.

IV. NEUTRON-INDUCED FISSION

The goal of this project is to study neutron-induced-fission isotopic yields. Before these studies can be undertaken, the experimental techniques discussed in Sections II and III must be completely tested and proven out using a ^{252}Cf source. The loan of a 3.7 mg ^{252}Cf source has been obtained. This source will be moved to the Center for Nuclear Studies in the near future and will be used as a neutron source for neutron-induced-fission experiments. The reconditioning of the neutron generator on loan from Texas Nuclear has required much effort and progress has been slow.

V. RECENT BIBLIOGRAPHY

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VI. WORK STATEMENT FOR ARPA PROPOSAL

The contractor shall conduct research involving the measurement of prompt fission processes. This research shall include, but not necessarily be limited to the following:

A. Studies of the spontaneous fission of ^{252}Cf employing various combinations of multi-parameter coincidence experiments. Parameters may include fission fragment, X-ray, alpha particle, gamma ray, time-of-flight, and neutron.

B. Studies of neutron induced fission of $^{235,238}U$ and ^{239}Pu employing various combinations of multiple parameter coincidence experiments described above, less the alpha particle measurements.

C. From an analysis of the above measurements begin a compilation of the total chain yield and the prompt isotopic yield ratios for fission of $^{235,238}U$ and ^{239}Pu as a function of neutron energy. Give priority to ^{235}U and ^{239}Pu fission mass distribution resulting from fission spectrum and 14 MeV neutrons.

VII. PERSONNEL

1 April 1972 to 31 December 1972

(a) NUCLEAR SCIENTISTS

C. Fred Moore, Professor (8 mo.*)	9 mo.
Patrick Richard, Assoc. Professor (4 mo.*)	5 mo.
Gerald W. Hoffmann, Asst. Professor (4 mo.*)	9 mo.
Larry L. Lynn, Research Scientist Associate III	4 mo.

(b) PRE-DOCTORAL APPOINTMENTS (GRADUATE STUDENTS)

John R. White, Research Asst. I	9 mo.
Forrest Hopkins, Research Asst. II	2 mo.

(c) ENGINEERING/TECHNICAL STAFF

Mary George, Administrative Clerk (9 mo.*)	9 mo.
Bonnie Wolf, Secretary (9 mo.*)	9 mo.
J.P. Coose, Technical Asst. III	9 mo.
Kenric Speed, Laboratory Asst. II	9 mo.
Hunter Ellinger, Computer Programmer I (9 mo.*)	9 mo.
A.L. Mitchell, Research Engineer III (9 mo.*)	9 mo.

(d) LABORATORY STAFF (UNDERGRADUATE STUDENTS)

Roger Jordan, Laboratory Asst. I	6 mo.
Claude Camp, Laboratory Asst. II	8 mo.
Jeffry Fitch, Laboratory Asst. II	8 mo.
Robert Hooks, Laboratory Asst. I	5 mo.
Gary Jacobs, Laboratory Asst. II	1 mo.
Nathaniel Smith, Laboratory Asst. I	3/4 mo.

* At no pay